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ABSTRACT

In the context of a research project on the role of prior knowledge state (PKS) in the learning process in a modular education system, a study of the literature was done in order to construct a conceptual map of "prior knowledge." In addition, a study was carried out in order to operationalize the concept of prior knowledge, to construct a conceptual map of prior knowledge terminology, and to investigate how the PKS could be operationalized using a number of variables. A questionnaire was developed to examine conceptualizations of the PKS and methods of establishing it. The questionnaire was sent to 27 Dutch and Flemish speaking experts who research prior knowledge, and responses were received from 17. Also explored were methods for measuring a student's PKS. Data collected from the literature review and from an enquiry among specialists are reproduced and interpreted to form a proposed model for research into PKS. Fourteen figures illustrate the discussion, with figure 5 depicting the proposed model and figures 1 and 2 in Dutch. (Contains 239 references.) (SLD)

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# Mapping 'Prior knowledge' or 'Expertise': a tentative outline

## *A conceptual map of prior knowledge and a model for research into the domain-specific prior knowledge state (PKS)*

F.J.R.C. Dochy

ED 384 616

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This research project started from the idea that if the specific prior knowledge is taken into account, in a modular educational system, students will have the opportunity of following different learning paths in a more efficient way. The research is directed at a clear definition of the problems and their solutions.

Educational Technology Innovation Centre

Open University

*Mapping 'Prior Knowledge' or 'Expertise': a tentative outline*

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**Summary**

Within the context of the research project on "the role of the prior knowledge state (PKS) in the learning process in a modular education system", a study of the literature was done in order to construct a conceptual map of 'prior knowledge'. Further, an in-case-study was carried out in order to operationalize the concept of 'prior knowledge'.
The objective of this study was to construct a conceptual map of prior knowledge terminology and to investigate how the PKS could be operationalized using a number of variables. Moreover, we looked into the question of the method to be used for measuring a student's prior knowledge state (PKS).
In this report the data collected in a study of the literature and from an enquiry among specialists are reproduced and interpreted. Finally, on the basis of the results, a model for the research of the PKS is proposed.

## Introduction

Looking at the literature of the last two decades in cognitive and educational psychology, it is striking that references to knowledge are frequently made and associated with all aspects of cognition and education.

Today, the research in cognition and learning places a lot of explanatory power in the constructs related to knowledge. It is, in fact, difficult to imagine describing a type of cognitive operation or learning process without a reference to some aspect of an individual's existing knowledge or expertise (Anderson, 1978).

Despite the numerous terms in use relating to prior knowledge, explanations of these terms are few and far between, and when they are given, they are too general and vague to be of much use. For example, when Neisser (1976) talks about the role of prior knowledge in perception, he describes prior knowledge as "the skills and experience of the observer" or, further, as "what he knows in advance". Marr and Gormley describe prior knowledge as "knowledge about events, persons, and the like which provide(s) a conceptual framework for interacting with the world" (1982,p.90).

Generally speaking, definitions of prior knowledge to be found in the literature are little more explicit than the two examples given.

The lack of precision in defining what is meant by prior knowledge and its related concepts can have serious consequences for research since researchers' and readers' interpretations of such knowledge-related constructs can have significant effects on reported results.
We would argue that only through an exploration and conceptualization of various types of knowledge, empirical research into the phenomenon can be advanced significantly.

With a study of the literature and an in-case study involving Dutch experts, we had four main aims, i.e.:

1. to examine the terminology associated with 'prior knowledge';
2. to examine that terminology as used by experts in the field of cognitive psychology and artificial intelligence;
3. to construct a conceptual map for 'prior knowledge' terminology that may improve understanding and promote future research; and,
4. to develop definitions for the key prior knowledge terminology to provide the basis for our further research.

First, we will comment on the use of 'prior knowledge' terminology and the problems revealing from this. We will give our view on categories of and differences in expertise. Further, after defining the basic terms, we will propose a conceptual map of prior knowledge or expertise. Finally, we will try to come to a valid indexation of prior knowledge by means of a literature study and the judgement of experts, in order to end up with a model for research into the domain-specific prior knowledge state.

# 1 A conceptual map of Prior Knowledge

## 1.1 The use of 'Prior Knowledge' terminology

In order to scrutinize the definitions and the uses made of the concept of 'prior knowledge', we conducted a literature review.
This study showed that clear delineations of the terms used were often missing. We found that in 25 out of 37 studies related to the subject of prior knowledge, no explicit definition was given. Alexander et. al. (1990) identified 67 articles published in Reading Research Quarterly since 1980 that referenced one of a family of knowledge constructs in title or abstract. Of those 67, 25 (just over one-third) referred to the term "prior knowledge". Only 9 of those 25 provided any explicit definition reflecting what the researchers meant by the term. Of course, it may be argued that such definitional statements are unnecessary because the meanings of the terms are commonly understood. However, our study of the literature, as well as Alexander's, suggest that even the most basic knowledge terms are not consistently defined. We illustrated this earlier by referring to the Neisser (1976) and the Marr and Gormley (1982) definitions of prior knowledge.

We came substantially to these conclusions : first we found that the manner in which researchers use the terminology of knowledge to identify their constructs, to state their objectives, and to direct their research activities frequently lacks precision. We cannot be assured, for example, that those who discuss prior knowledge as a principal variable in their research are not really testing or treating some more specific dimension of that subsuming construct. Mostly, it is not clear which part of the whole construct they are treating. Likewise, when researchers claim to be investigating domain or discipline knowledge, and when they fail to define, at least implicitly, what they mean by such terms, then we may need to question the validity of the undertaking (see also the Alexander et al. study, 1990).

## 1.2 Problems revealing from the use of prior knowledge terminology

In the various theories and research on prior knowledge, descriptions and definitions of the terminology are almost exclusively nominal. A great deal is made of the distinction between nominal and real definitions in the indexation and representation of concepts. In nominal definitions, the user introduces the meaning of the term by stipulation. Anyone who does not know the construct is directed towards the meaning within which the construct is used. Nominal definitions of the construct "prior knowledge" are much in evidence in the literature. They are largely described as "the totality of knowledge and skills of the subject" or "what he knows already beforehand". Real definitions are few and far between. Perhaps this conclusion can be related to another conclusion from this study, that is that prior knowledge thus far has been virtually exclusively measured by means of existing tests.
In a real definition, the manner in which the definition of a construct replicates reality is pivotal. The characteristics that the object does or does not meet are given. For example, some authors distinguished between two dimensions: information and skills; others stress the availability or the amount of prior knowledge. A main problem with knowledge terminology is that authors use different terms to refer to what appears to be the same construct. In the English speaking world, in which the phenomenon is most widely studied, various terms are used interchangeably. "Prior knowledge" is used, but there are also terms such as 'prestorage', 'permanent stored knowledge', 'prestored knowledge', 'knowledge store', 'prior knowledge state', 'prior knowledge state in the knowledge base', 'implicit knowledge' or 'archival memory'. Also 'background knowledge', 'experiential knowledge', 'world knowledge', 'pre-existing knowledge' and 'personal knowledge' are used as synonyms. According to Alexander, Pate, Kulikowich, Farrell, & Wright (1989) for instance, the terms "domain" or "domain-specific knowledge" , "content-specific knowledge" and "subject matter knowledge" all signify knowledge about a specific field of study (e.g. economics). Still other researchers use a variety of terms, such as "discipline knowledge", "topic knowledge", "background" or "prior knowledge" (e.g., Beck, McKeown, & Gromoll, 1989) to represent what might be better termed as "domain knowledge". By contrast, some researchers discuss subjects' prior knowledge or domain knowledge when what they are more accurately referring to is passage-specific, topic knowledge (Langer & Nicholich, 1981).

The review of the literature revealed six categories of problems associated with the usage of terminology related to knowledge terms. Specifically, across studies

a. nominal definitions prevailed over real definitions of prior knowledge related concepts;
b. the used knowledge concepts were mostly not defined;
c. subcategories of knowledge were inconsistently incorporated;
d. different aspects of knowledge were referred to by the same terms;
e. the same aspects of knowledge were referred to by different terms;
f. the interactions among the different aspects or kinds of knowledge were represented differently or ignored.

## 1.3 Categories of prior knowledge

In the research into cognition and learning, the broad term 'knowledge' has been broken down into subsidiary concepts. A number of cognitivists use the dichotomy of declarative and procedural knowledge, others talk of episodic and semantic knowledge. Still others talk about the use of strategic knowledge. It is possible not only to make a distinction in terms of the content of the prior knowledge, but also in terms of the scope of the area of knowledge to which it refers. These differences will be explained briefly below.

*Declarative knowledge and procedural knowledge.*

Conceptual knowledge (Posner, 1978), largely called declarative knowledge, is the knowledge of facts, the meanings of symbols and the concepts and principles of a particular field of study. Cohen (1983) even limits this to facts. Sometimes propositional knowledge is referred to (Greeno, 1980) or descriptive knowledge (Lodewijks, 1981). Knowledge of action, manipulation and activities are indicated by De Jong (1986) as procedural knowledge. Cohen (1983) talks of skills, rules, procedures and plans.

*The distinction between declarative and procedural knowledge.*

The essential difference between declarative and procedural knowledge is that procedural knowledge refers directly to action or activity, while declarative knowledge requires an interpretation in order to lead to action (Messick, 1984). For example, Anderson (1980) distinguishes between declarative and procedural knowledge as "knowing that" and "knowing how" respectively. Cognitive skill is closely related to procedural knowledge and is described as the ability to carry out various intellectual procedures. Anderson (1980) goes on to say that "most declarative knowledge can be expressed verbally while much procedural knowledge cannot.... However, declarative knowledge need not be verbal". The distinction leads to two currants of scholarly research into 'machine intelligence': to the first, the proceduralists, knowledge is procedural and is concerned with how; and for the second, the declarativists, knowledge includes both propositions ('knowing what') and general procedures to manipulate them.
In our own research we sometimes will differentiate between declarative and procedural test items. This difference, according to the above and based on De Corte's work (1976) on the taxonomy of goals in the cognitive domain, will be operationalized as follows: items measuring the appreciation, the recognition and the reproduction of information will be viewed as declarative; items measuring production or applications (interpretative, convergent, divergent or evaluative production) will be viewed as procedural.

*Episodic knowledge and semantic knowledge.*

Episodic knowledge reflects the totality of personal experience in its spatio-temporal context, and is comparable to a historical document. Episodical knowledge is contextual and accidental. Semantic knowledge includes a representation of the external world, abstracted from its context. This knowledge is largely expressed in terms of 'models of memory' as a system of related concepts, including what are called 'nodes'.

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*The relationship between episodic and semantic knowledge.*

According to Cohen (1983) in practice there is no sharp distinction between the types of knowledge. Each model which makes a distinction must also be provided with an interface between episodic and semantic knowledge. How often do we have to see a leopard to know that its spots are a defining characteristic ? 'Permanent stored knowledge' arises on the basis of new episodic inputs.
Using concepts like episodic and semantic knowledge is difficult. In practice the distinction cannot be made clearly. For this reason we shall, in the present study, restrict ourselves to the use of a somewhat better defined concepts of declarative knowledge and procedural knowledge.

*Strategic knowledge.*

Strategy can be seen as a general plan of action in which the sequence of the separate cognitive activities is laid down (Posner and McLeod, 1982). This is primarily important in the solution of problems in which the following different phases have to be gone through: analysis, planning, implementation and verification (Schoenfeld, 1979; Mettes and Pilot, 1980). Strategic knowledge directs the thinking process, but the boundaries to the use of this knowledge are thus far unclear. For that reason there are no explicit theories, as yet, on the content of this knowledge (Brown, Collins and Harris, 1978). The conceptualization of this type of knowledge is very vague. Cohen (1983) makes no distinction between it and procedural knowledge. Both comprise skills and plans of action.
According to De Jong (1986) the difference resides in the degree of specificity. Procedures related to a small part of the solution process are largely domain specific, and include algorithms and heuristic devices. Strategies are related to the whole process of solution and are often used more with subject content (Schoenfeld, 1983; De Jong, 1986). There is, however, never a question of a strict dichotomy, but rather of a sliding transition. After all, the terms, procedural and strategic, are often used interchangeably.

*Experiential knowledge.*

Further, it has been thought necessary to look at the importance attached to experience as a source of PKS. More research has been directed at the role of experience preceding a learning activity primarily under the influence of the "experimental learning school" in the US. In the Wagemans and Dochy research report (1989) experiential learning is further analyzed. We define experiential knowledge as 'regardless of where learning occurs, it is the knowledge and skills acquired through life, work and study, which are not formally attested through any educational or professional certification'. It is that part of the factual prior knowledge state which is not formally recorded.

*Domain specific knowledge and domain transcending knowledge.*

Recent research has pointed the fact that both domain specific knowledge and domain transcendant knowledge exists in the knowledge base (Glaser, 1984). Furthermore there is evidence that learning is far more domain specific than earlier theorists of learning believed, i.e. concrete and practical situations seem to be better learning environments than highly abstract ones (Shuell, 1986; Tuma and Reif, 1980). Carey (1985) suggests that the acquisition of knowledge during the total period of development i.e. throughout a person's life, is based on increasing knowledge within various domains. This 'domain specific restructuring view of development' has received a great deal of support in research on novice-expert differences within various domains, such as physics (Chi, Glaser and Rees, 1982; Larkin, McDermott, Simon and Simon, 1981; McCloskey, Caramazza and Green, 1980), chess (Chase and Simon, 1973), radiology (Lesgold, Feltovich, Glaser and Wang, 1981) and the social sciences (Voss, Greene, Post and Penner, 1983). Nevertheless it is unlikely that all learning is domain specific. If this was the case, it would be difficult to explain how individuals deal with new situations or how they handle entirely new information. Viewed objectively, learning, according to Shuell (1986), comprises domain specific and domain independent processes. How these processes interact with one another is as yet unclear. Glaser's hypothesis (1984) is that undue emphasis on specific or on more transferable content knowledge in instructions will vary as a function of the competence or prior knowledge of the learner and the characteristics of the domain. According to Glaser, a useful approach to research is to learn the domain specific knowledge so that the more general (self-regulatory) skills are practised during this learning (Glaser, 1984).

## 1.4 Differences in prior knowledge or expertise

A well known distinction in prior knowledge, often made in cognitive psychology, is that between the expert and the novice. Norman (1978) describes an expert as someone who has studied a complex subject for a period of 5000 hours, and during that time has thought about it on a daily basis and has also learned to use the information. The distinction between a novice and an expert mostly resides in the amount of prior knowledge which they have at their disposal. The difference in prior knowledge or expertise influences the manner in which they learn. Mirande (1981) gave a psychology text to a beginning student and an expert, and asked them to draw up a schema of the text and a list of specifications of the concepts used. In studying the text, the student approached it on the basis of: what can I learn from this text? He added new knowledge to his stock of knowledge. The expert asked: how is this subject dealt with? During the reading process she was continually assessing, and comparing the knowledge in the text with her own knowledge. In schematizing the expert included more concepts in her scheme than the student, while her list of specifications had an entirely different content. The abbreviated schemes of the student (see figure 1) and of the expert (see figure 2) show how markedly their accounts differed. For the student it is a text about three sorts of tests. For the expert it is a text about three critical observations on part of a text about tests by a particular author.

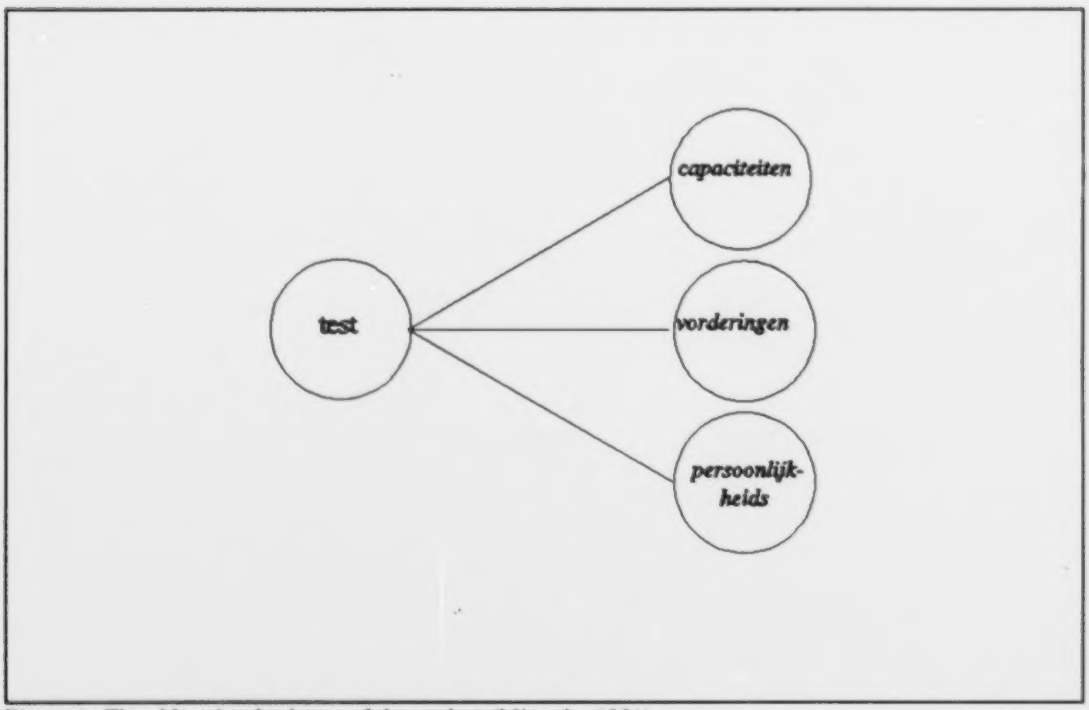


Figure 1: The abbreviated scheme of the student (Mirande, 1981).

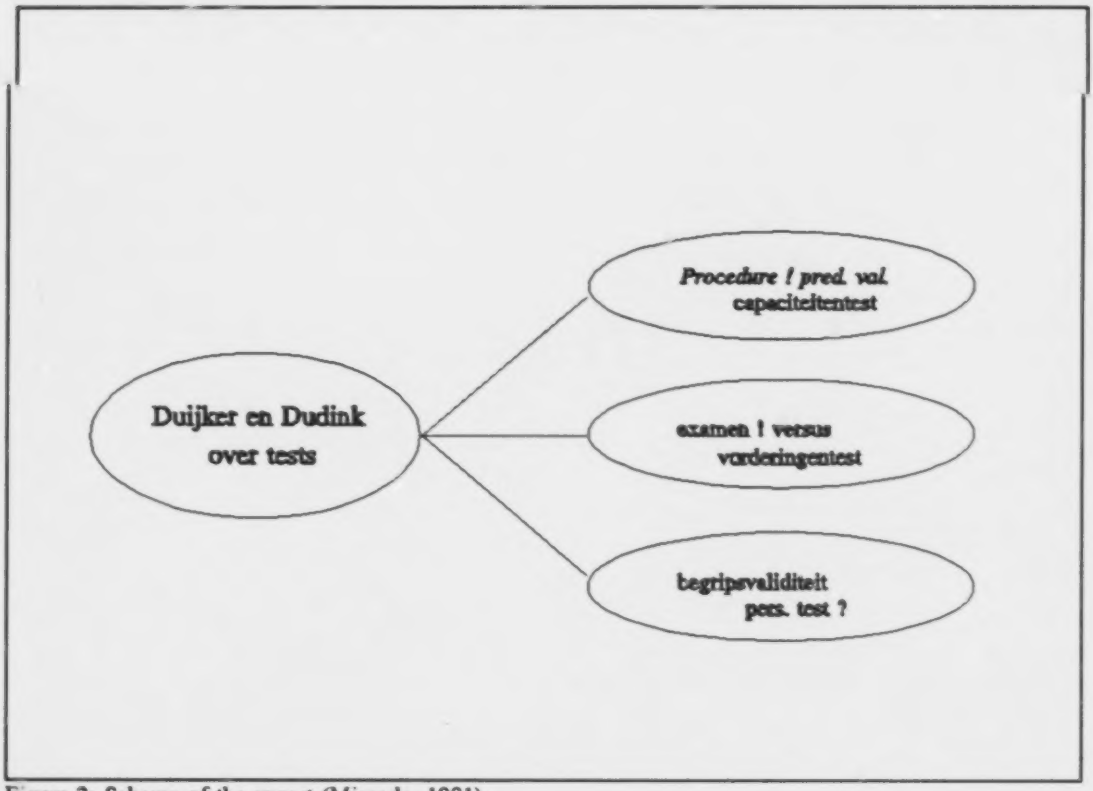

Figure 2: Scheme of the expert (Mirande, 1981).

*Research into the differences between novices and experts.*

Differences between novices and experts were primarily investigated in respect of the solution to problems. Chi, Feltovich and Glaser (1981) carried out three experiments in which problems in mechanics were offered for solution.

They concluded that experts had a different cognitive structure, comprising what are called problem schemata. An adequate problem schema includes elements of declarative and procedural knowledge that are valid for that specific type of problem, in addition to knowledge of problem situations. In listing everything that is of use in the solution of various sorts of problems, experts and novices mentioned the characteristics of problem situations equally frequently. Experts appeared however to be able to name more explicit procedures (if-when relations). Chi and others (1981) concluded from this that experts have explicit solution procedures in their specific problem schemata, related to the characteristics of problems. Larkin, McDermott, Simon and Simon (1980) and Elshout (1982) discovered that experts are more thorough in their analysis of the problem. Beginners/novices appeared to jump quickly to the solutions and omit stages in the analysis and transformation which experts pay attention to. According to Larkin et al. (1980), Chi et al. (1982) and Been and Brokken (1984) in the statement of the problem, experts are able to more easily discover the characteristics relevant to the selection of the solution procedure. Experts also make fewer errors and reach a solution more efficiently by means of a 'means-end analysis', (Larkin et al., 1980). Analogous expert - novice differences were discovered in both the solution of natural science problems and in the positing of a medical diagnoses (Schmidt, 1982, Dijkstra, van der Stelt, van der Seijde, 1983). Differences between experts and novices can be reduced to the following differences in knowledge and skills

(Reif, 1981; Jansweijer and Elshout, 1984; Mettes, 1984):

a. Differences in methods of problem analysis.
The novice does not have:
- a variety of models of problem schemata to choose from.
- an analytical or categorization system for problems.

b. There are differences in declarative knowledge.
- this knowledge is more complete and more coherent in the expert
- the beginner fills in the missing knowledge with naive knowledge and ad hoc theories of idiosyncratic proposals for processes or states.

c. Differences in procedural knowledge.
- the expert has better organized more wide ranging production schemata, associated with more explicit conditions for application and categories of problem situations.
- the expert's knowledge is structured so that the same information (the declarative information too) is present at different levels of detail.
- the beginner does not have a systematic solution plan.
- the beginner has problems with the application of general knowledge in specific situations.

In our work, when 'prior knowledge' will be used as a synonym of 'expertise', we hold a broad definition of prior knowledge as reflected in our conceptual map. This means that in those cases, one should take account of the content knowledge ( declarative and procedural) and the metacognitive knowledge.

Limited power of generalization and problems associated with the expert-novice paradigm.
The results of the above research have to be interpreted with caution.

First, they are virtually exclusively concerned with research into problem solution and not with learning as a whole.

Second, the research primarily concerns problems of natural science and medical problems and furthermore problems at a relatively simple level, i.e. well defined problems of a specification type (Mettes and Pilot, 1980; Schmidt, 1982).

Third, caution in interpretation is recommended because the expert-novice paradigm is not a true paradigm. In the research above, beginning students are largely used as novices, staff or graduates as experts. But who is a novice and when does one become an expert? People who have completed their education in a subject or have a number of years experience in that area are taken to be experts. Graduates, teaching staff, professors, but also students who have pursued a course, and have studied with success are also regarded as experts (Jansweijer, Elshout and Wielinga, 1985). So there can be a great deal of difference between different experts.
Furthermore, being an expert is related to a field of study or domain specific knowledge. An expert in education can be a novice in chemistry.
Determining the beginner's level of expertise, however, seems to be much more arbitrary. In the research of De Groot (1946), Dijkstra et al. (1983), Chi et al. (1981) and Larkin (1979), the novice experimental subjects already had a certain amount of expertise in the domain (De Jong, 1986). In other research, such as that of Egan and Schwartz (1979), Mourant and Rockwell (1972) and Shavelson (1974) beginners were categorized as being 'uninformed', 'having little knowledge' or 'an almost complete lack of experience'. Beginners are thus defined at different levels and are virtually incommensurable as a homogeneous group. Gradually cognitive researchers have come to realize that beginners, certainly when defined as those who have acquired some insight into the domain, are a heterogeneous research population. With this in mind, Silver (1981), Finegold and Mass (1985) and De Jong (1986) investigated the differences between weak and



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good beginning problem solvers. Moreover, more and more scientists agree on the need to define and to assess levels of expertise more accurately.

Fourth, in respect of the power of generalization of these research results, note should be taken of the often rather small number of experimental subjects; they range from two to eight.

Finally, the assessors of protocols were often informed of the level of expertise of the experimental subjects. This could bias their assessments.

Although we should interpret the results of expert - novice studies with some caution, they have been of great value to the understanding of the learning process and specially to the development of conceptual modelling and cognitive mapping.

### 1.5 Constructing a conceptual model and defining the basic terms

Before we present a conceptual model of prior knowledge, it seems useful to state our own definitions of the basic terms we will further use in our research and that will be part of the presented map.
The main goal of this section is to come to a clear model of a person's expertise or prior knowledge.
Prior knowledge in our view is the total of a person's existing knowledge, partly tacit and partly explicit, containing content knowledge and metacognitive knowledge, and which is dynamic in nature.

Explicit knowledge is knowledge that is currently employed as an object of cognitive activity and is directly interacting with the world along the interface between the learner and what is being learned. It is thus time and situation specific. Explicit knowledge can be used or unused at a certain moment, but at a particular moment and for a particular task,it is all immediately accessible.

Tacit knowledge is not directly interacting through the interface and resides at a deeper level. At a particular moment and for a particular task, this knowledge can be elevated (partly or completely) to an accessible level a;though not immediately. For example, not having spoken a language for years makes it tacit. When used again it may be only half remembered. Tacit knowledge is thus half-remembered knowledge in the sense that it cannot be instantly recalled at the learning 'interface'.

Apart from the flux between used and unused explicit knowledge and tacit knowledge, the main subdivision of prior knowledge is that of content knowledge and metacognitive knowledge.

Content knowledge, as a part of one's prior knowledge, is the knowledge of some aspect of one's physical, social, or mental world, and can be formally or informally acquired. The formalization or specialization of content knowledge is presented in our framework by the presence of the substructures for domain and discipline knowledge. As a concept becomes more a part of the formal system of learning or central to a specialized field of study, it becomes part of the substructures of domain or discipline knowledge. The relationship between content, domain, and discipline knowledge, therefore, is hierarchical and is based upon their degree of specialization. Moreover, these categories are not to be seen as generic ones.

Research over the last two decades has directed attention towards domain-specific knowledge. Figure 3 gives our model of domain knowledge.
The vagueness of concepts like 'domain', 'subject', is a problem when they serve as a basis for prediction (Ennis, 1990). Therefore it is highly advisable to state the meaning of domain specificity and domain clearly beforehand.

Domain specificity is the empirically based view that learning or thinking (a) requires prior knowledge, (b) is unlikely to transfer from one domain to another without explicit transfer-inducing instruction, and (c) is unlikely to be learned from general learning or thinking instruction.
According to Ennis (1990) there is complete agreement about the first principle, a majority of educational psychologists agree with the second principle, but psychologists and the research on the third are not in agreement (Ennis, 1989).

Domain knowledge is a more formal subset of content knowledge. It is the total of content knowledge concerning one particular field of study or academic domain, such as law, economics, psychology.

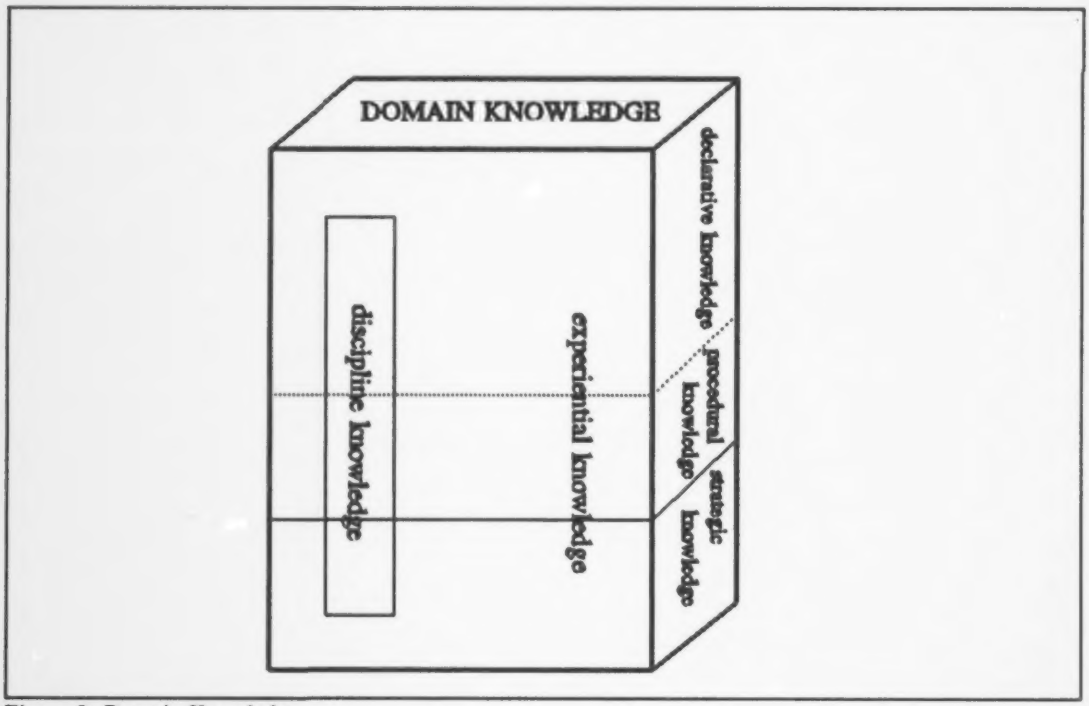


Figure 3: Domain Knowledge.

Discipline knowledge is a formal part of a certain domain knowledge. It is used as a synonym for course-specific knowledge. It contains a specialized field of study, mostly covered by one academic course.

In our study, we will use that concept of domain to refer to 'economics'. Further, this domain is broken up into financial economics, accountancy, micro-economics, macro-economics, etc., called disciplines.

Metacognition, as a part of prior knowledge, is the knowledge about one's own cognition and the regulation of that cognition (Flavell, 1987). Figure 4 gives a model of metacognitive knowledge.

In Flavell's use of the term "metacognition", it "refers to the part of one's acquired world knowledge that has to do with cognitive (or perhaps better, psychological) matters" (1987, p.21). According to Flavell tripartite subdivision of metacognitive knowledge, we will hold three categories metacognition related to person, task, and strategy: self knowledge about learning needs and -plans, task knowledge and strategic knowledge.

Self knowledge about learning needs and plans entails individuals' perceptions or understandings of themselves as learners or thinkers. It involves knowledge of what cognitive tasks an individual performs best or worst, how an individual's performance compares to those of others, which learning strategies one uses. Further, it involves the plans individuals internalized and their learning needs, influenced by affective understandings about themselves (Alexander, et. al, 1990).

Task Knowledge includes knowledge of analyzing the types of cognitive tasks that are encountered (Alexander, et. al,1990). It involves knowledge of the goals individuals establish and the recognizing that different types of tasks place different demands on learning or thinking. Task knowledge also holds a kind

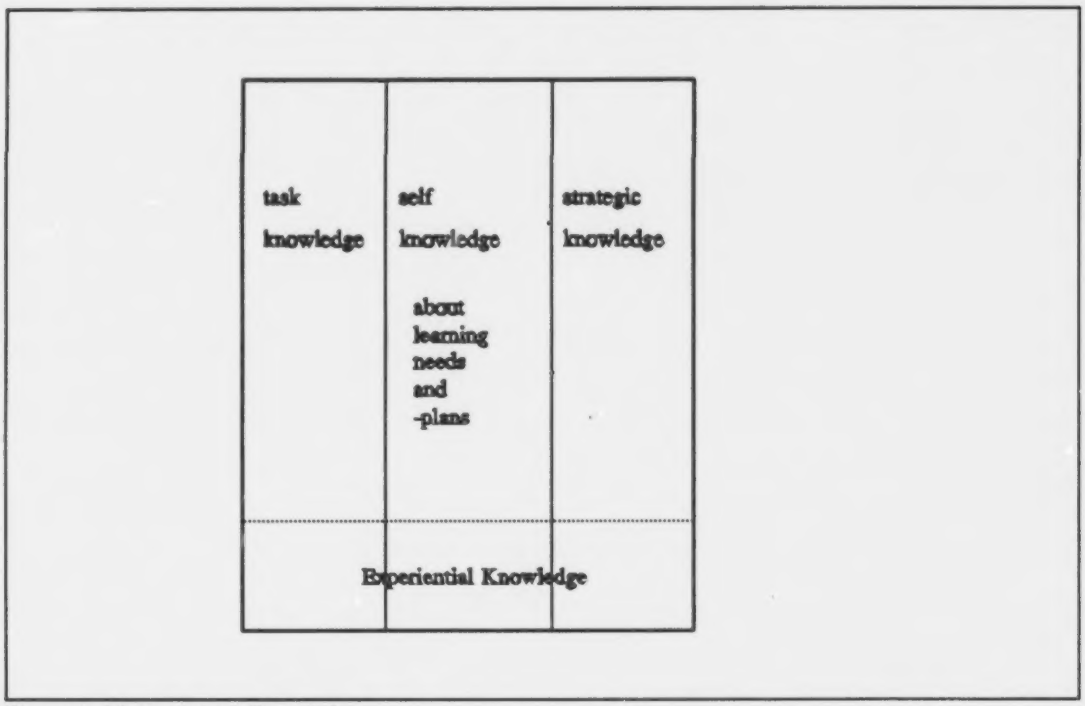

Figure 4: Metacognitive Knowledge.

of cost - benefit analysis in that it allows the learner to balance the importance of completing a task with the amount of cognitive demands of a given task (Pressley & Ghatala, 1988).

Strategic knowledge, in our view, plays a role as a part of content knowledge as well as metacognition. The first procedure used in the completion of a task is a cognitive strategy, since it relates directly to the fulfilment of the designated task (Flavell (1987) and Garner (1987)). The second procedure is not to complete the task but to evaluate or monitor how well the selected cognitive strategy is working, i.e. a self-checking procedure that is an example of a metacognitive strategy. Therefore, the conceptual framework holds in both areas of content knowledge and metacognitive knowledge a certain amount of strategic knowledge.

The knowledge interface is a bridge between prior knowledge and external conditions, includes the "instantiation" of knowledge, which is built from the activation and utilization of the individual's prior knowledge, and the "textbase" (Anderson, et. al., 1990).

"Instantiation" (R.Anderson, Pichert, Goetz, Schallert, Stevens, & Trollip, 1976; Schallert, 1982) occurs from the dynamic interaction of existing knowledge structures built upon prior experiences with available information from on-going experiences. Through instantiation, individuals "particularize" the abstract representations or understandings that they are forming (R. Anderson, 1984). Thus, in this interface, the learner builds a meaningful framework from existing knowledge that will facilitate the interchange between what is already known and what is to be understood.
This notion of an interface between internal knowledge structure and external stimuli is important because it emphasizes not only that the system of knowledge within the individual is dynamic but also that this system in continually in flux as a consequence of its interaction with the world external to it.

## 1.6 Conceptual map of Prior Knowledge or Expertise

In the following section, we present our attempt at understanding these knowledge constructs by showing how the terms are related to one another in a conceptual framework (figure 5).

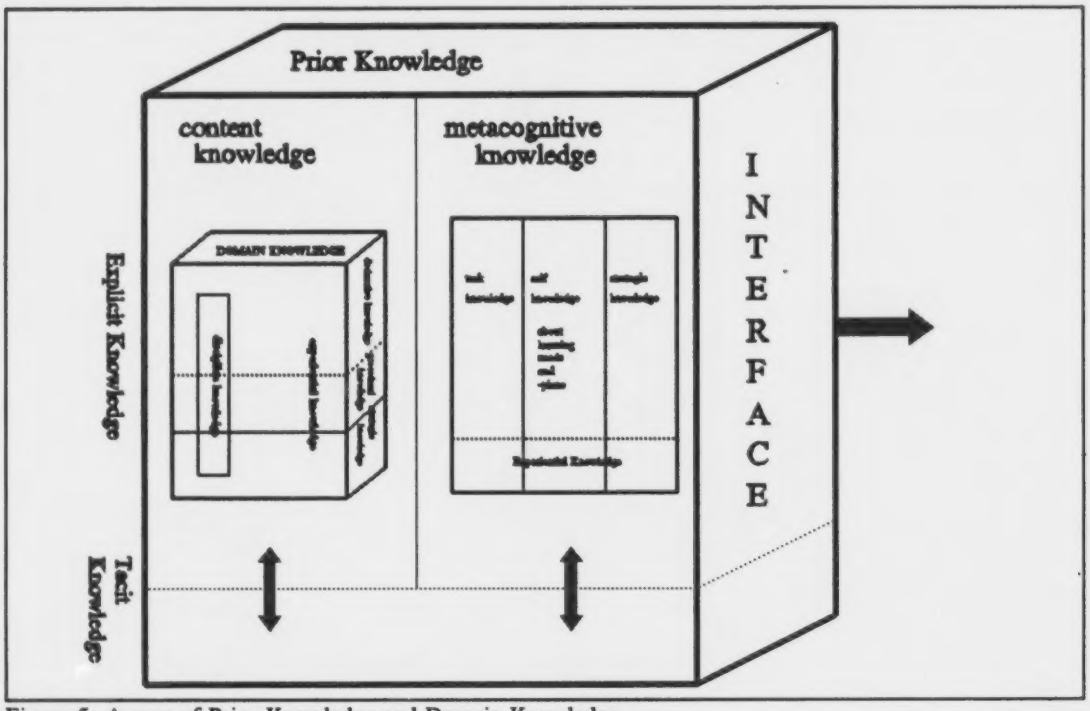


Figure 5: A map of Prior Knowledge and Domain Knowledge.

This conceptual map, although illustrating the relations between the concepts so far presented, may be somewhat misleading. As it portrays the conceptual map of knowledge as a snapshot or 'slice-out-of-time' representation, it may be thought to represent a static, non-interactive view of knowledge. Therefore, we state some basic assumptions about our view of knowledge, assumptions that do not receive direct representation in the visual display.

The conceptual framework focuses on a system that represents an individual learner's prior knowledge.
The framework is meant to be a conceptual map and not a processing model of knowledge use.
We hold that forms of knowledge are fluid and dynamic. Not only do these forms vary between individuals but they vary within individuals as well, as a consequence of person, task, or context variables. Further, the forms of knowledge we display can vary in terms of position, order, or size.
It is also a premise that all forms of knowledge are interactive; that is, the presence or activation of one form of knowledge can directly or indirectly influence any other. When confronted with an ill-structured problem about supply and demand, for instance, an adult learner may call upon related content knowledge (e.g., her knowledge of what items department stores mark down for sales) to bolster her weaker, formal knowledge of economics. This interactivity of knowledge has been well illustrated by the work of Voss et al. (1986), Alexander et al., (1989) and others (Walker, 1987).
Knowledge cannot be dichotomously labelled as tacit or explicit. Just as the forms of knowledge are fluid and dynamic, so are the "pieces" of knowledge that combine to make up those forms. Tacit and explicit knowledge exist in a state of dynamic interaction for specific tasks. Unused explicit knowledge can become used explicit knowledge. Likewise, knowledge can also function tacitly under different circumstances.
Although we recognize that other conceptual maps can be valid too, we tried to construct it from the point



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of view that it should be useful in practice and empirical research. Another, in our opinion more theoretical model, was constructed by Alexander et. al. (1990) (see figure 6).

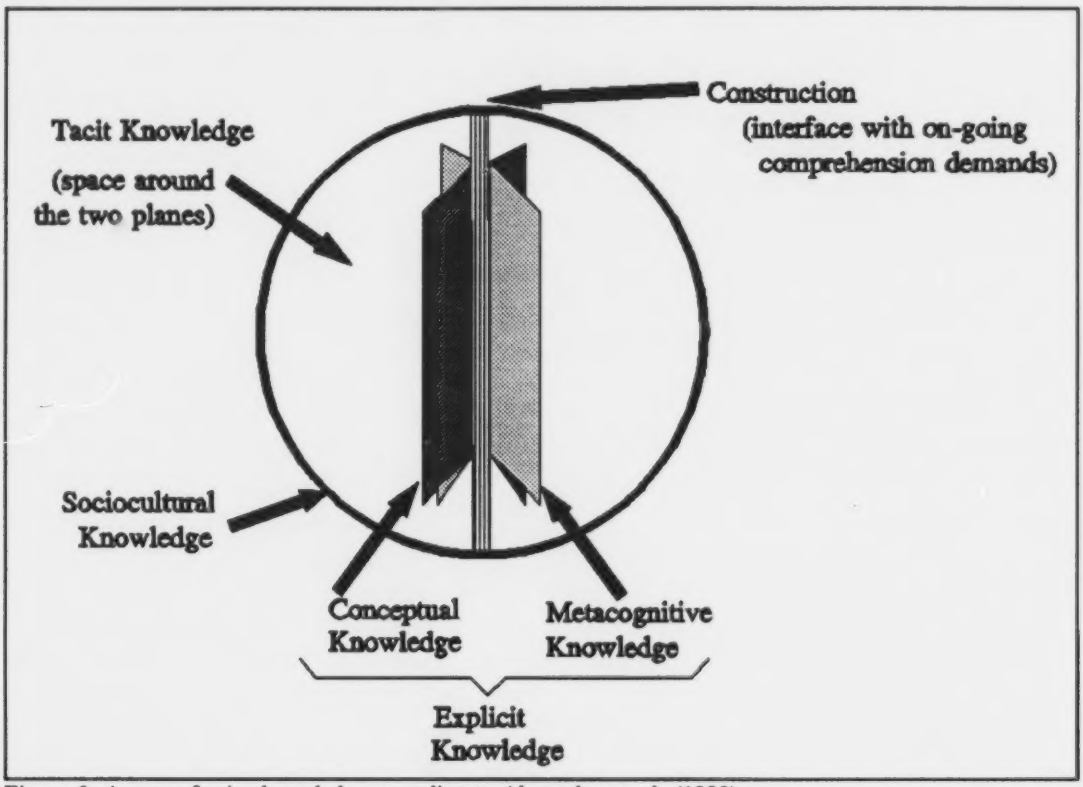


Figure 6: A map of prior knowledge according to Alexander et. al. (1990).

This 'propeller model' has some important differences compared to our 'barrel model'. Anderson presents sociocultural knowledge as a different category and excludes, at least explicitly, the experiential knowledge from her model. In our view, the experiential knowledge is a part of prior knowledge. Further, the propeller model does not show how for example declarative and procedural knowledge fit into it, although Alexander et. al. pay a considerable amount of attention to these concepts in their studies.

### 1.7 Research into students' knowledge states

In this section, we want to clarify our further research approach in terms of choices made to investigate the prior knowledge of students. Therefore, we will stress the importance of a clear delineation of the concepts 'Prior Knowledge State' (PKS), 'Domain-specific Prior Knowledge State' and our view of learning as a transition between knowledge states. We want to stress that the use of the concept 'knowledge state' is not changing our view on learning and knowledge acquisition as a dynamic process.

One should take account of the current tendencies in higher education and the progress in educational research. This means that it should be noted that, since prior knowledge is seen as an important variable, research into the assessment of knowledge states became a central issue in educational psychological research. Then learning could be viewed as a successive transition between knowledge states.
By 'knowledge state' we mean a state of prior knowledge as measured. On the basis of the positions taken in our conceptual map of prior knowledge and taking the ultimate importance of domain specificity for

granted as we will argue further on, we will direct our research mainly towards content knowledge, i.e. the 'domain specific prior knowledge state' (see figure 7). This indicates that the concern is with domain specific knowledge at a particular moment, in this case prior to learning an assigned learning task. Bransford (1979) speaks of the "current level of previously acquired knowledge and skills".

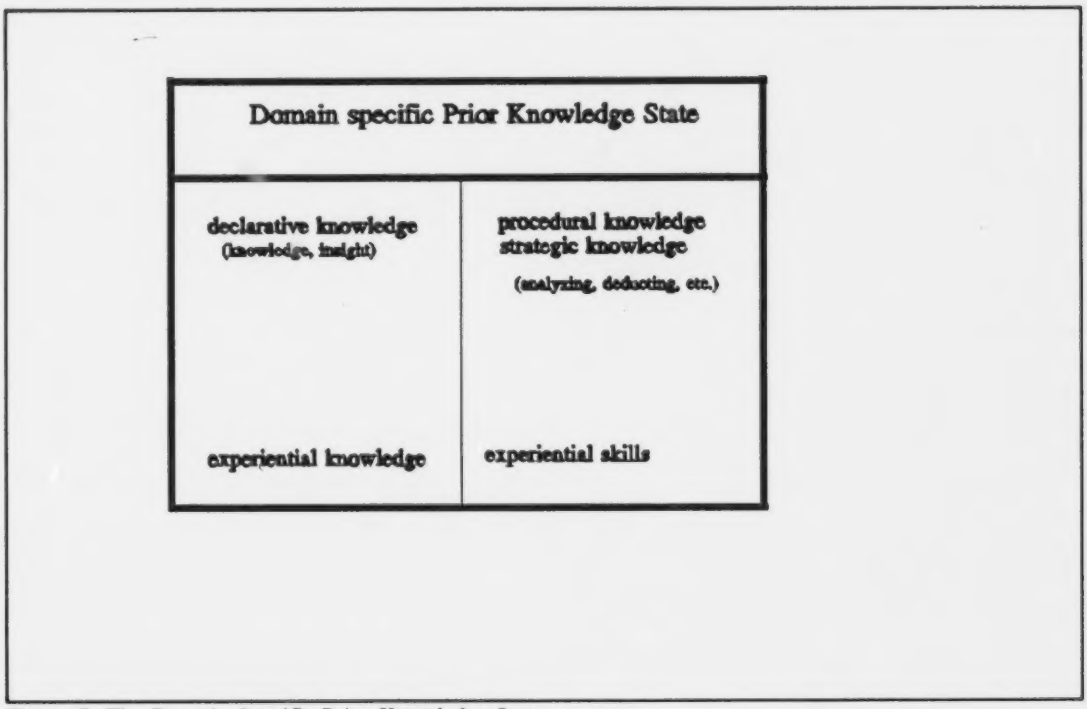


Figure 7: The Domain-Specific Prior Knowledge State.

New educational developments seem even to stress this kind of research into knowledge states.
First, there is the tendency towards lifelong learning and adult education. The student population will extend and will become even more heterogeneous than it is; they differ in age, in education, in work-experience, etc. So taking the prior knowledge state into account could enhance the learning process of the student and lead to better course design and instructional support.

Second, since modular education becomes more integrated, one of the pivotal aspects is the multifunctionality of modules. This means that the more interchangeable the modules are, i.e. useful in various faculties, various programmes of various degrees, in different universities and several countries, the more interesting for institutes and the cheaper they become. The main factors however, in this, are the insight in the prior knowledge state of students and the ability to handle or to use the PKS.

Third, in the development of Knowledge based Systems (KBS), there is a need to know more about the student model, containing especially information about the student's prior knowledge state. KBS contain four important components (figure 8):

1. the domain expertise,
2. the pedagogical expertise,
3. the interface,
4. the student model.

The student model, illustrated in figure 8, is used to gain a clear understanding of the student's knowledge state and to make hypotheses about his or her conceptions and reasoning strategies employed to achieve the current knowledge state. In the past, too less attention has been paid to the development of the student model.

When learning is viewed as successive transition between knowledge states, the purpose of instruction is accordingly to facilitate the student's transversal of the space between knowledge states. This definition involves two basic types of activity:

- attempts to determine the student's current knowledge state;
- attempts to cause or support a transition to the next state.

For this reason, the research project was divided in two parts. A first part, investigating into how to determine the student's prior knowledge state, its role in the learning process and the construction of a set of knowledge state tests and knowledge profiles.
A second part of the project is directed towards the development of a Knowledge Acquisition Support System prototypes (one of the starting points of the actual KASS project) (Koper, 1989; Koper,1990).

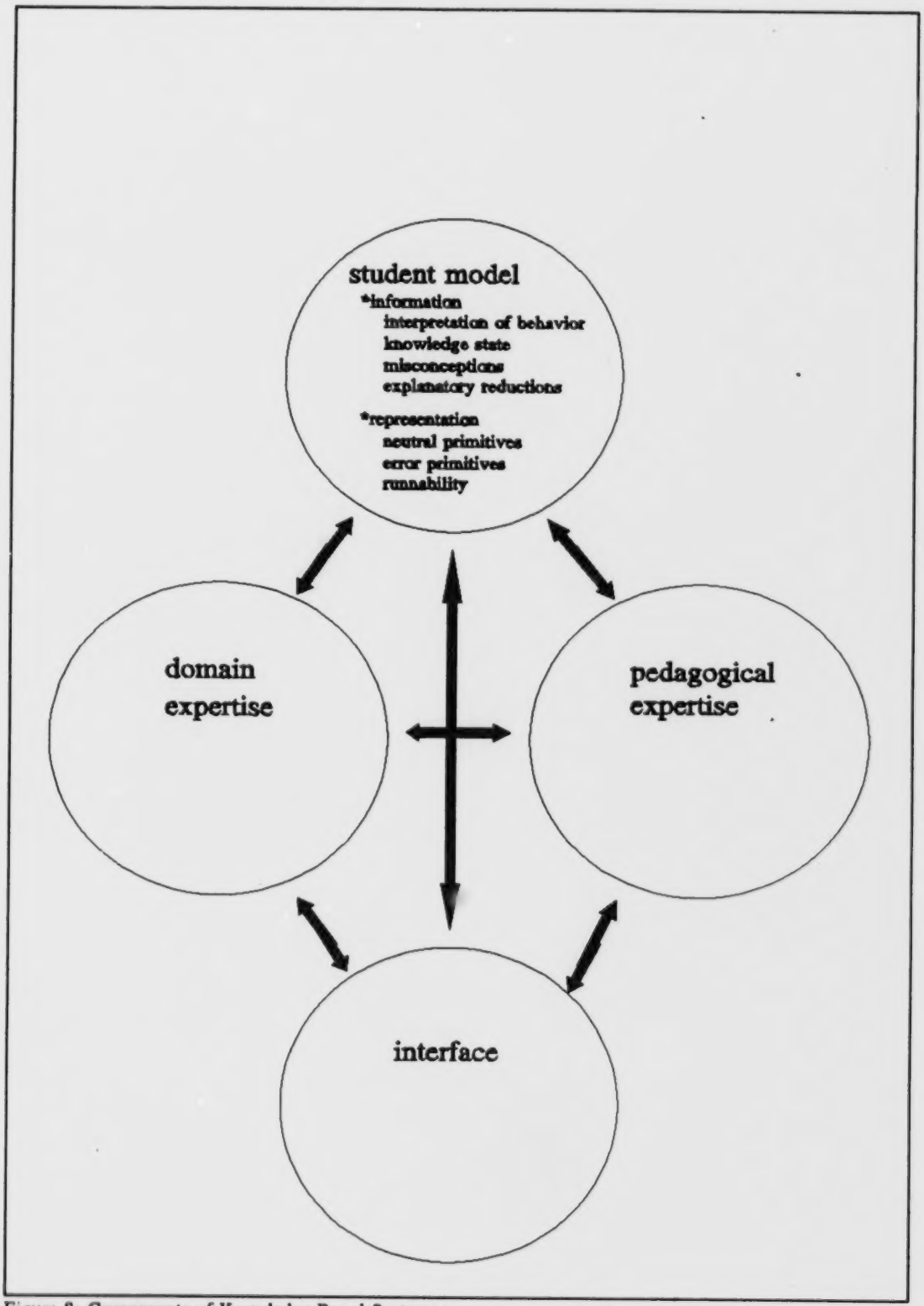


Figure 8: Components of Knowledge Based Systems.

## 1.8 Conclusion

Without some consistency in usage of the terminology of prior knowledge or expertise and without explicit and precise definitions of these concepts, researchers and readers run the risk of misconceiving the studies and misjudging the results.

For one thing we are well aware of the limitations under which we operated. We recognize that this is only one possible conceptualization of these knowledge terms. We realize that evolution of knowledge about knowledge is continuous as is the generation of labels needed to describe that evolution. Further, we understand that the framework we have devised has been significantly influenced by the literature we have examined and by our own research activities. First of all, these models are constructed to guide discussions in our research and to locate our research activities on the map of cognitive research into the role of prior knowledge.

The research described resulted in the proposed conceptual model (figure 5). Operationalizing the properties selected into usable measuring instruments will be described in a following report. Prior to that, the proposed model will be tested in educational practice by means by interviews with students and existing methods for the establishment of variables will be analyzed.

# 2 A valid indexation of the 'prior knowledge' concept based on literature and views of experts: Towards a model for research into the domain-specific Prior Knowledge State

In this section we will explain the terms "validity", "indexation" and "operationalizing" that are used extensively below.
The pivotal questions in this case study are : which variables indicate the existence of prior knowledge on the part of students ? Which variables represent the "prior knowledge state" in a valid way?
Further on, we will try to come to an indexation of the prior knowledge by means of a study of the literature and the research into the perception of experts with reference to the prior knowledge.

## 2.1 Validity

Segers (1977) writes that the concept of validity relates to the question of whether the theoretical characteristic at issue can be ascertained by means of the phenomena selected. The validity principle means that research data must be such that it is legitimate to move from the level of empirical variables to that of theoretical concepts.
Carminus and Zeller (1979, p.12) formulate this simply by saying that "an indicator of some abstract concept is valid to the extent that it measures what it purports to measure." De Groot (1961) uses the terms "concept-as-meant" and "concept-as determined". The requirement that the variable represent the concept-as-meant as adequately as possible is a special requirement in respect of the relationship between concept and (operationally defined) variable. "The issue is whether the variable is valid in being representative, or whether the "validity" is that of a variable. A variable is valid if it is representative of a theoretical, more abstract concept; this means that a theoretical characteristic can be measured in terms of empirically chosen phenomena.

## 2.2 Indexation and operationalizing

There is no clear consensus about the meaning of the terms indexation and operationalizing.
Segers (1977) introduces in our view a clear and useful distinction between indexation and operationalizing within the process of translation from the theoretical to the empirical. The significance of these terms and their interdependence is made clear in figure 9.

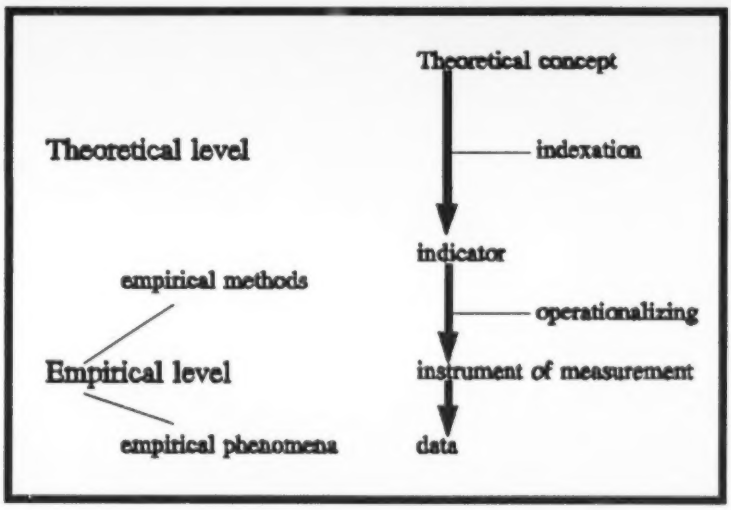


Figure 9: Indexation and operationalizing (Segers, 1977).

In this study, we shall use this distinction as introduced by Segers.
Operationalizing takes place in this schema at a different level from the one at which Swanborn (1984) places the concept. Segers regards indexation as the first step in the "translation" of the abstract concept and operationalizing as a second step, in particular, the translation of the empirical phenomena into an instrument for measurement in the narrow sense (for example questions, a thermometer, a test...). Indexation is according to Segers also valid when the chosen indicators accord in their meaning with the theoretical concept.

A concept can often distinguish more than one dimension. Indexation is only valid when all aspects are represented in the indicators, which are distinguished in the definition of the concept as a dimension. In our case, Segers (1977) advises to track the dimensions from research into the literature. The validity of the dimensions should be confirmed by experts in the field. The operationalizing of a two-dimensional concept was mapped out by Segers (Figure 10).

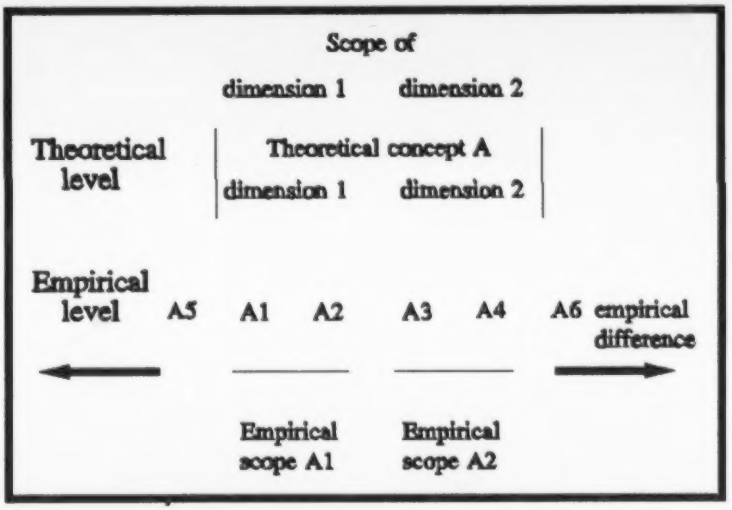


Figure 10: Operationalizing of a two-dimensional concept (Segers, 1977)

A1 A2 valid indicators for dimension 1, invalid for 2
A3 A4: invalid indicators for dimension 1, valid for 2.
A5 A6: invalid indicators for both dimensions.

Within the context of the significance that we assign to the concepts indexation and operationalizing, valid operationalizing relates to the validity of the instrument of measurement.

### 2.3 Indexation of the "prior knowledge state" concept

When applied to our research, it means that first we turn our attention to the indexation of the concept. The different indicators or dimensions - both are largely used as synonyms - and the characteristics are examined in this. In one and the same situation, various aspects of a concept-as-meant are often active at the same time. For that reason most constructs are reduced to their various components as the first step in indexation. The distinguishing of variables is also a first step on the way to operationalizing. The concept-as-meant, i.e. the prior knowledge state, is divided into separate aspects which can be distinguished from one another.

These aspects are ranged along dimensions. Each of these dimensions is further divided in variables or characteristics.
The questions to be put in this research are : what aspects represent the concept-as-meant, i.e. the prior knowledge state, in its various dimensions ? What aspects are seen as representative of the dimensions distinguished or what characteristics adequately cover the indicators to be measured ?

## 2.4 Methods of validation

Generally speaking, the following methods are distinguished : content validation, criterium validation and construct validation. Note that the relationship between the instrument of measurement and the criterium is pivotal in criterium validation; in construct validation the theoretical construct is pivotal.
In this case it is a question of content validity.
Other terms for content validity are : logical validity, face validity and sense-validity. Segers (1977) claims that "the relationship between the construct-as-meant (theoretical characteristic) and construct-as-measured (empirical variable) is supported by arguments which indicates that the "content" of the indicator accords with the "content" of the theoretical characteristic. Face-validity is the assessment of indicators on their "external appearance" as a representative of a theoretical concept or dimension.

The consensus that can arise within a scientific forum about the validity of an indexation raises face-validity, from a methodological point of view, above pure subjectivity. The judgement of experts (fellow-researchers, content experts) determine content validity. Content validity can however only be approached when the researcher pays attention in the first instance to the quality of instrumental design. Segers (1977) distinguishes theoretically four essential stages in the design of a content valid instrument :

a)theoretical concern with the elucidation of the significance of the content of the construct involved;
b)the recognition and specification of the theoretical dimensions of the construct;
c)the careful choice of indicators for each of the dimensions distinguished;
d)the assessment of the manner in which the different indicators have to be joined to one valued determinant.

Boesjes-Hommes (1974) agrees with Segers that content validity can be approached by calling upon assessors. He speaks in this connection of substantive testing used to investigate the equivalent in the semantic meaning of a construct and its operational derivatives.

In this project we shall investigate whether the content of the dimensions accords with the theoretical construct of the "prior knowledge state". This method of content validation which accords with the various stages distinguished by Segers (1977) includes a theoretical discussion in the research and also a theoretical consideration and elucidation of the theoretical construct. This is by means of a study of the literature and an in-case study on PKS within a scholarly forum, i.e. among various experts in the area of cognitive psychology and artificial intelligence.
This inter-subjective assessment by experts will in the first instance be directed at the validation of the significance of the concept and its potential dimensions that should be measured. The relationship with assessment instruments will be discussed later on. This means that we first will face the semantic and structural equivalence. The functional equivalence will be discussed in the research group and tested by the results of the exploratory study of other investigations into prior knowledge, in order to select promising and useful instruments.

## 2.5 Indexation by means of research into the literature and the judgment of experts

### 2.5.1 Research into the literature and research into the perception of experts with reference to the PKS

In the first instance our study of the literature refers to the use of prior knowledge (PK) by students in higher education, research in the area concerning the use of prior knowledge and expertise in education and theories on the facilitating influence of prior knowledge. This study is reported on in research report 1: "The effect of the prior knowledge state on learning: theories and research".
A second piece of research into the literature is directed at the indexation of the concept of "Prior Knowledge State" (PKS). In this section, we shall examine these results.
Apart from that, a questionnaire was constructed comprising general questions on the significance of the PKS construct i.e. domain specific prior knowledge and the methods of establishing it. Potential



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respondents in this investigation were all experts in the area of Cognitive Psychology or Artificial Intelligence. In order to make a selection from this group of experts who were active in research on prior knowledge, an inventory was made of the Dutch and Flemish speaking experts during the study of the literature. A questionnaire was sent to 27 experts.
Replies were received from 17 who answered all the questions.

### 2.5.2 Indexation of the "prior knowledge state" concept

Real definitions come more often from the experts than the literature. Relevant descriptions are given here. The descriptions that proceed from know-how already acquired, i.e. prior knowledge that has a clear influence on performance (see research report 1, page 1) provides little that helps to make the construct of prior knowledge usable and they are not included here. For example, the statement that prior knowledge is that part of a person's knowledge that influences the learning, processing, reproducing and using new material in a given situation. Such definitions do not say what prior knowledge is, but what has been established by means of research.
A second example is the following quote : "In the natural sciences and mathematics it can be stated that the ability to solve a type of problem gives an indication that the student possesses the prior knowledge necessary to learn a particular part of the subject. In this "reversed" situation the performance is supplied by solving problems or carrying out work which is unjustly regarded as the proof of the influence of prior knowledge.
As stated before, the definitions in literature are so vague that it would be hardly possible to make an indexation. The questionnaire study with study with experts resulted in more real and concrete definitions. The Prior Knowledge State was described by experts as for example:

- the degree to which the student already possesses knowledge/insight/skills. It is not just a question of the presence of particular element or skills, but also the structure of knowledge, the degree to which knowledge, insight and skills are associated with stimuli so that the student is able to activate and use them at the right moment.
-the domain information present in his or her memory which is in principal accessible and can be recalled. Access and the ability to recall something does not imply that the student must be able to (re)produce the prior knowledge by himself and from within himself. Knowledge which can be (re)produced with the help of hints, cues, tasks is to be seen as prior knowledge.
-in general it is organized within a cognitive structure that makes it more or less easy to apply in the process of understanding dependent on the nature of the structure. In addition to organization, the ease with which prior knowledge is activated within the text to be studied or the learning context is an important determinant of the learning process.
-the knowledge that a learner has in the area in which he is to be further trained or taught. Prior knowledge can be practical knowledge and theoretical knowledge.
-all the knowledge that is already stored in the memory before the "criterion task" was initiated and that becomes active in the carrying out of the task (for example learning new material) .
-all existing knowledge of the subject. (Facts, definitions, laws, procedures, situations, etc.) necessary for absorbing and processing the new knowledge, and which is there to fall back on in education (textbooks). It is not only the content that is important, but also the availability of the prior knowledge; this is to an important degree determined by the structure of the knowledge.
-possessing one or more schemes in which newly acquired knowledge can be applied.

After a content analysis of all responses, it appears that the experts highlight a number of PKS characteristics. Emphasis is on five aspects : the presence of knowledge, insight and skills, its structured nature, its dynamic nature (ongoing updating), the availability of information required; knowledge and skills, present before the implementation of learning activity. Experts mostly refer to domain knowledge or knowledge about subjects.
Moreover there is also in the literature a tendency towards research into the domain-specific prior knowledge.

In accordance with the literature and the meaning of experts, in our research we will try to investigate mainly the domain-specific expertise of students. Metacognitive prior knowledge was investigated by

Vermunt (1985) and is a major point of attention in the research on Knowledge Acquisition Support Systems by Koper (1989,1990). We will argue on this choice more extensively later on.
In using the concept of PKS further on, it will mostly get the meaning of 'domain-specificity'.

In summary, this means that research is directed at declarative knowledge - called 'information' - and procedural and strategic knowledge - called 'skills' at the domain specific level.

In this study the Prior Knowledge State can be described as the knowledge state comprising existing declarative knowledge (information and insight) and procedural i.e. strategic knowledge which meet the following conditions :

-they are present before the implementation of a particular learning task
-available or able to be recalled
-relevant for the achievement of the objectives of the learning task
-organized in structured schemes
-to a degree transferable, applicable or transferable to other learning tasks, within and possibly outside the domain
-dynamic in nature.

The Prior Knowledge State can be schematically presented as a knowledge state that comprises a particular moment (before the implementation of a learning activity) that is available for the achievement of particular learning objectives (figure 11).
In the literature and among experts there is general consensus on a number of aspects which reveal the PKS. These are part of the proposed indexation.

| THEORETICAL CONCEPT: | | PRIOR KNOWLEDGE STATE |
|---|---|---|
| dimension I | dimension II | dimension III |
| variables 1,2,3,... | variables 1,2,3,... | variables 1,2,3,... |

Figure 11 : Indexation of the PKS

## 2.6 Provisional conceptual model for research concerning the Prior Knowledge State

From the above, eight properties can, in principle, be derived for a conceptual model for research into PKS :

1. the nature and amount of prior knowledge
2. the availability of prior knowledge
3. the structuring of the cognitive structure
4. the relevance of information in respect of the learning objectives.
5. the pace or duration of the learning process
6. durability of what is retained
7. previous education
8. work experience (and age).

Further a limited number of properties which give a valid indication of prior knowledge : pace of study, durability of what is learned, education and work experience.

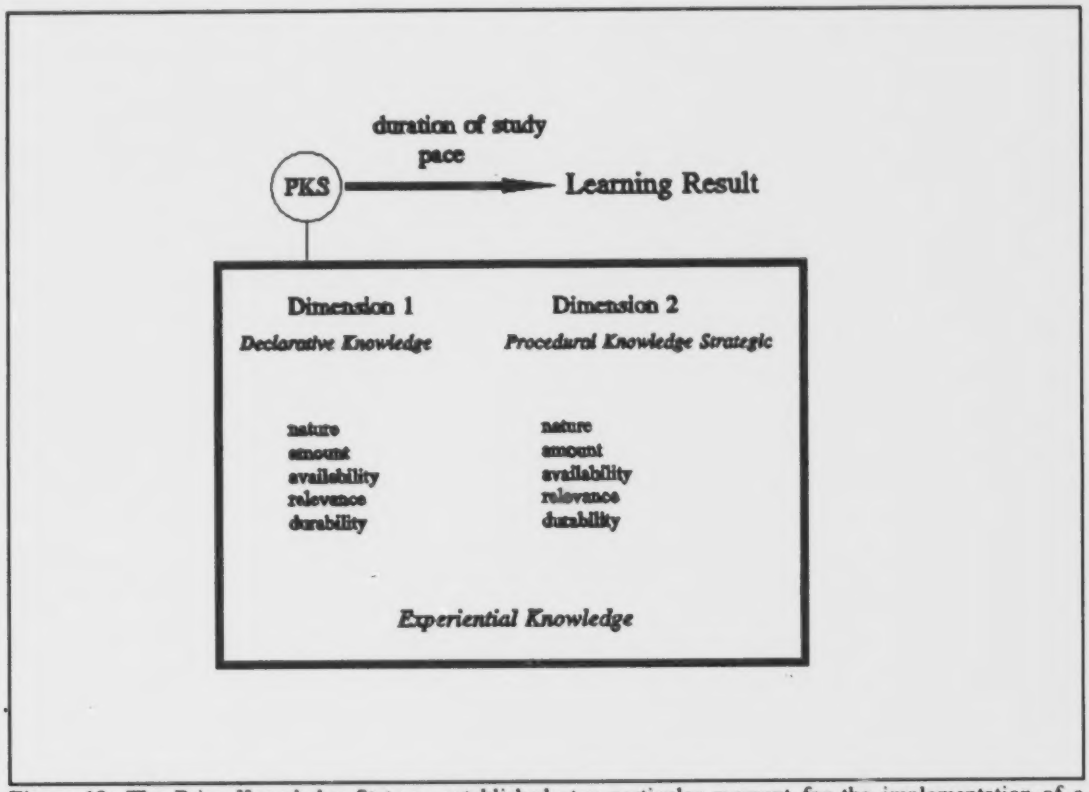


Figure 12: The Prior Knowledge State as established at a particular moment for the implementation of a learning activity.

## 2.7 Operationalizing the different aspects of the Prior Knowledge State and related measurement instruments

When investigating the role of prior knowledge in the learning process, the first question after the indexation of the concept is the operationalizing into useful assessment instruments.

Coming to the problem of how to assess the prior knowledge state of students, it seems logical to try first the easiest i.e. the less time consuming and cheapest method.
Earlier research showed that prior knowledge has a substantial influence on study results. In this view, measuring prior knowledge by means of a single indicator which is available would be the first possibility. Or also by means of a combination of several available indicators (Dochy et al.,1990). For example, variables as sex, age, work experience, previous education and others could correlate with or could be significant predictors for the study results of students. If this was the case, it would be worthwhile looking closer at a variable that correlates strongly with prior knowledge.
These possibilities will be tested in the ex post facto research and experiments described later.

Beneath that, as indicators will never give us information on the properties of prior knowledge and thus will not be very helpful in enhancing educational practice and the student's learning, different prior knowledge tests will be developed. These different tests will be related to the different properties of the student's PKS (prior knowledge state) (figure 13). From the information received from experts in the field, as described earlier, and from research into literature, we tried to operationalize the different characteristics in order to connect them to assessment instruments.

According to the six aspects of the PKS, we found several tests in literature that showed possibilities to measure them.
Moreover, we tried to go beyond the 'soccer type' of prior knowledge tests. For this reason we did send a questionnaire to the economists of the university of Hairline and Maastricht and to different experts in educational testing at Dutch universities. The aims of this were to investigate the need for different sorts of prior knowledge state tests (KST), to inform about former used KST and to find procedures for developing new kinds of KST.

The economists did find two sorts of tests of crucial importance to look for the student's prior knowledge state.
A discipline KST, defined as a test measuring the knowledge that is provided in a specific course, and the mathematics KST, being a test measuring the required mathematics knowledge for following the course, i.e. at end secondary education level.
Economists and educationalists agreed on the necessity of using a domain specific KST, being a test providing information on the student's knowledge concerning the whole domain of economics, divided in different subdomains.
Further, educationalists stressed the importance of using cognitive structure tests and portfolio assessment.
Finally, some of the respondents suggested to take account of the optimal requisite knowledge (OR). This optimal requisite KST intended to assess the content knowledge that is required to study the course in optimal conditions. Of course, it was meant to aim at the content knowledge that is not available in the specific course (and which is included in the discipline specific KST).

Most of these tests are used in educational testing, although some of them are not widely known and mostly not used as assessment instruments for prior knowledge. As noted in our review of research, short discipline specific and mathematics KST are often used to measure prior knowledge. At the university of Limburg, the PES (Project for Evaluation of Study results) and Imbos (1989) have been experimenting with domain specific knowledge tests to assess prior knowledge and the development of that knowledge.
In literature evidence was found that a method called 'error analysis' can provide useful information on the availability of the prior knowledge and partly on the nature of prior knowledge in terms of incorrect prior knowledge or misconceptions (Alexander et al., 1989).

In total, we found seven possible assessment instrument in order to catch a picture of the student's prior knowledge state:
1. A discipline specific KST (knowledge state test).
2. A mathematics KST.
3. An optimal requisite KST.
4. A domain specific KST.
5. A cognitive structure test.
6. An error analysis procedure.

The construction and content of the tests we will use in our empirical studies will be described later.
At this point, we will explain the connection between the different aspects of the KS we want to measure and the assessment instruments. This explanation will be based mainly on the literature (Alexander et al., 1988,1990; Chiesi et al., 1979; Ennis,1990; Freebody et al., 1983; Glaser,1984; Hare, 1982; Langer,1980, 1981; Matthews, 1982; Prawat, 1989) and partly on personal communication with scientists (Wijnen, De Corte, de Wolf, Segers, Kroksmark, Drottz, Sjöberg; 1989 -1991).

Figure 13 gives an overview of these theoretical relations.
We will describe them shortly.

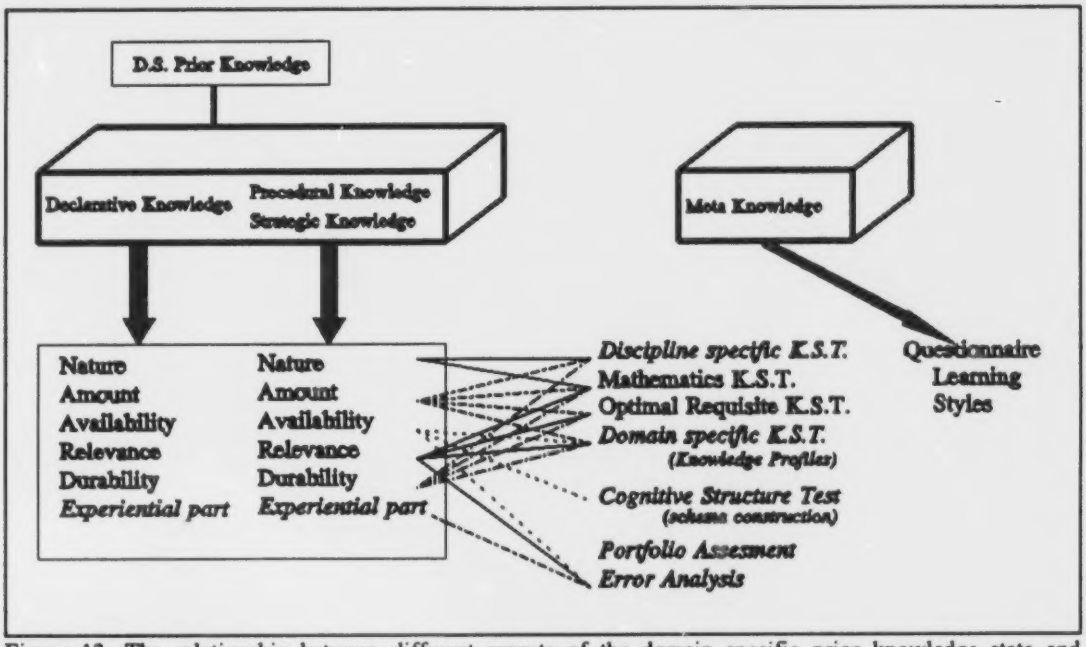


Figure 13: The relationship between different aspects of the domain specific prior knowledge state and knowledge state tests.

1. The nature of the prior knowledge state can be measured by the discipline KST, the math KST and the domain specific KST. While the discipline KST and the math KST provide limited information on the relation of the PKS with the course content or mathematics, the domain specific KST gives an overview of the PKS within the whole domain (e.g. economics) and within the different subdomains (e.g. micro economics, macro economics, accountancy, etc.) To make this overview visible, easier to interpret and available for students, we developed a 'knowledge state profile' based on this test (for examples see further).

2. The amount of prior knowledge can be measured by means of all KST, which will provide each information on the amount of a certain kind of prior knowledge: course specific, maths, optimal requisite and domain specific prior knowledge.

3. The availability of knowledge, being the ability to draw on or utilize resources, is closely related with accessibility. Some authors use the two concepts as synonyms, other claim that accessibility is one step further. Available knowledge can or cannot be accessed. As viewed in most research, access is largely a function of two important factors: organization and awareness. Connection between key concepts and procedures provide the glue that holds the cognitive structure together. The adequacy of this structure, in turn, determines the accessibility or availability of resources at a later time. By means of a cognitive structure test information is provided on the availability and accessibility of prior knowledge. Also the domain specific KST gives some indications on the availability of knowledge within a domain.

4. The relevance of the prior knowledge state can mainly be tested by two instruments. First, the optimal requisite KST measures the required and relevant knowledge that is necessary to follow the course. Secondly, error analysis makes by means of patterns of errors a sort of map of the irrelevant knowledge that was used.

5. According to the mentioned literature, durability of knowledge can be assessed by means of all KST in a repeated testing procedure.

6. The experiential knowledge can be assessed by means of portfolio assessment, as earlier advocated in Wagemans & Dochy (1989).

## 3 The scope of our studies: the choice for domain specific prior knowledge

From our interviews among experts, we concluded that they mostly focus on domain specific prior knowledge.
By means of an updated literature study (up till end 1990, we looked for evidence for further focusing our studies on domain specificity.
It is obvious that the experts in the field of educational and cognitive sciences are influenced by scientific articles and writings, but our worry here was to find out if there is a new fashion or rather a justified trend.
In this paragraph we will argue our design and the choices made for our empirical studies on the base of recent contributions to a theory of expertise.

### 3.1 Contributions to a theory of expertise.

Cognitive research assumes that what guides actions are the schemata or cognitive structures that reside in individual minds. Some studies of expertise defined these structures for various academic and practical tasks, with the underlying subsumption that novices could be taught the knowledge structures that experts use, and thus become experts themselves.
More recent cognitive studies contributing to a theory of expertise begin with defining expertise from the perspective of prior knowledge that is used in practice, leading to the speculation that the acquisition and the use of expert knowledge is more tightly bound to particular contexts than was assumed earlier (Lampert & Clark, 1990).

Looking at our model of expertise, it is clear that using prior knowledge involves the two different parts, i.e. the content directed part and the metacognitive part.

The literature on skilled problem solving and expertise research has led to the identification of three categories that should be mastered with a view to approaching a task appropriately and with a fair chance of being successful (De Corte, 1990):
1. flexible application of a well-organized domain-specific knowledge base;
2. heuristic methods, i.e. systematic search strategies for problem analysis and transformation;
3. metacognitive skills.

To limit the scope of our further research however, we will focus in the rest of this study only on domain-specific knowledge. In the first studies we will be concerned with De Corte's first category. When necessary for the implementation of research results in practice, we will scrutinize heuristic methods.

There is a considerable amount of evidence that the domain specific prior knowledge is the part that is most affecting the learning process and results.

The importance of domain-specific knowledge has been well demonstrated for students of different ages (Glaser, 1987; De Corte, 1990). It was even found that domain-specific knowledge already strongly affects the solution processes of young children on arithmetic word problems (De Corte & Verschaffel, 1987).
Above all, the DS- prior knowledge should not be mixed up with the overall general ability called intelligence. In the fifties, one still believed that more intelligent people could learn things that less intelligent could not. A careful inspection of empirical findings makes this doubtful for some reasons. First, the correlation between intelligence and achievement is highly variable. Statistical meta-analyses have yielded overall coefficients that range between .34 and .51 (Fraser et al., 1987). Second, if one partial out the influence of prior knowledge, the correlation between intelligence and study result is drastically reduced to values ranging between .0 and .30 (Weinert, 1989).

Further, the results from studies on metacognition show remarkable parallels with the results from intelligence studies looking at predictors of learning outcomes (Weinert, 1989). According to his statistical analysis of available data, Scheider (1985) found a significant correlation of .41 between metacognition and performance. But again, Weinert (1989) replicated the study, partializing out the effect of prior knowledge, and concluded that the former conclusion did not hold any longer. The correlations between metacognition and performance diminished just as much as in the intelligence case i.e. a decrease between .34 and .21. (r



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was between .07 and .20). Even on the basis of other studies Weinert (1989) concluded that "contrary to expectations, past research has shown that motivational variables and instructional characteristics make very little contribution to the prediction of school performance". This is in agreement with Schmidt's opinion (1987).

In our view, Weinert (1989) concluded properly that the basic postulate of the new approach is: domain-specific knowledge (rather than the intellectual ability or the metacognitive competence) determines the process and outcome of learning and reasoning.
Earlier, we have advocated that we deal this opinion, but one should remember that in our view, the reason for the lack of evidence of effects of intelligence and metacognition is caused by the nature of the assessment instruments.

Convincing evidence for the prior knowledge effect is provided by the earlier cited work of Weeda (1982) and certainly the study of Bloom (1976) and the synthesis of meta-analyses by Fraser et al. (1987) revealing a fairly high mean coefficient of .75 for the factor of domain-specific knowledge in predicting school achievement.

Further investigating the role of domain-specific prior knowledge concerning the topic of 'soccer', Weinert (1989) did find a strong impact of prior knowledge on performance. The correlations between prior knowledge and performance remained significant even with intelligence scores partialed out. Also he concluded that domain-specific knowledge can compensate for low intellectual ability, but a high intellectual ability cannot compensate for a low knowledge base. This pattern of results coincides with the study by Walker (1987), using baseball texts. Moreover, in this study, Weinert found that metacognition played a role: a high level of metaknowledge was related to a better performance independent of soccer expertise. Out of these studies emerged that the combination of domain-specific knowledge and general metaknowledge leads to especially good performance. Körkel (1987) analyzed the relations between age, intelligence, metacognition, prior knowledge and performance through a correlational pattern. Figure 14 gives the LISREL model representing the parameter estimations for the structural relationships.

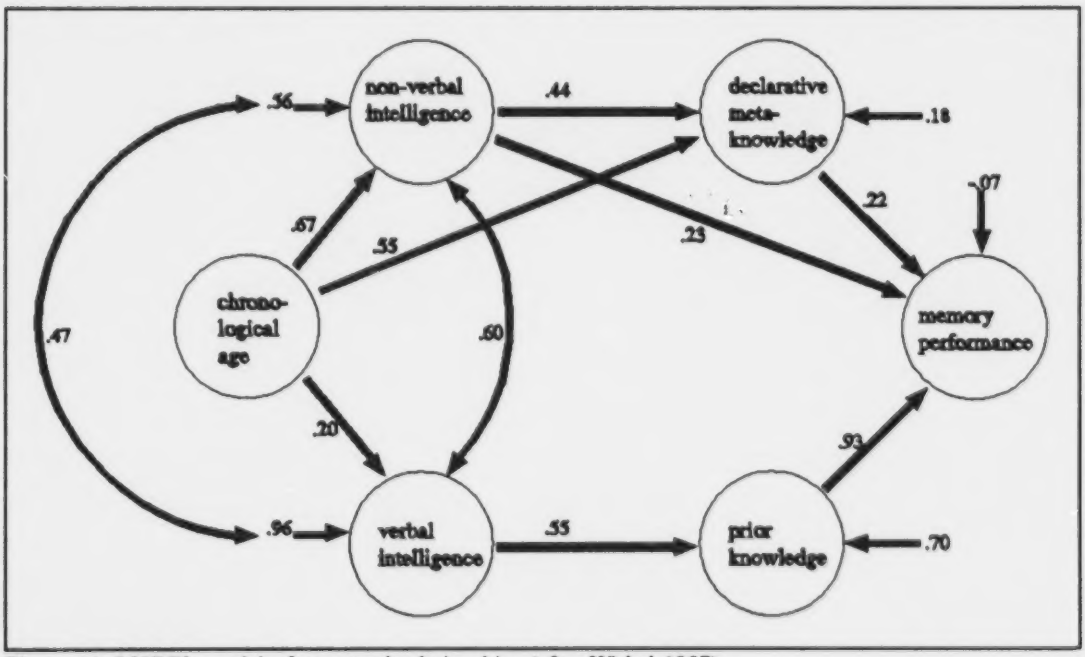


Figure 14: LISREL model of structural relationships (after Körkel, 1987).

The most important finding again is the superior explanatory power of content-specific knowledge, i.e. the most significant path in the model.

In a replication of the soccer study, Weinert (1989) found that domain-specific knowledge is a decisive prerequisite for good mathematics achievement.

Overall, he concluded that "the past is in fact the best predictor for the future. Differences in the knowledge base are the main source of intra- and interindividual differences in cognitive achievement, irrespective of chronological age or the specific domain of knowledge".

## 3.2 Conclusion

Without some consistency in usage of the terminology of prior knowledge or expertise and without explicit and precise definitions of these concepts, researchers and readers run the risk of misconceiving the studies and misjudging the results. For one thing we are well aware of the limitations under which we operated. We recognize that this is only one possible conceptualization of these knowledge terms. We realize that evolution of knowledge about knowledge is continuous as is the generation of labels needed to describe that evolution. Further, we understand that the framework we have devised has been significantly influenced by the literature we have examined and by our own research activities. First of all, these models are constructed to guide discussions in our research and to locate our research activities on the map of cognitive research into the role of prior knowledge.

We did not state that earlier research into prior knowledge did not contribute to a theory of learning. Our message is that a clear model of prior knowledge enables others to interpret correctly which part of the student's knowledge has been investigated and fosters more valid conclusions over several studies.

The research described resulted in the proposed conceptual model (figure 5). Further we argued the operationalizing of the properties selected into usable assessment instruments, from which some will be used in our empirical studies.

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